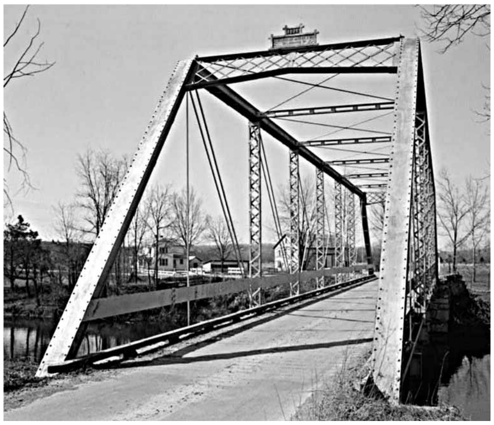
The Learning Activity

The Problem

The Need

Just outside the small town of Hauptville, New York, Grant Road crosses Union Creek via a beautiful old 19th Century Pratt truss bridge similar to the one shown here. Recently, the Town Engineer determined that the structure is no longer safe for modern truck traffic and must be replaced. Because of its historic value, the old bridge will be disassembled, moved to a nearby public park, and rebuilt as a pedestrian bridge. A new highway bridge for Grant Road must be built on the existing site.



Design Requirements

The Owner for this project is the Town of Hauptville. Several months ago, the Town Council selected Thayer Associates, a respected local engineering firm, as the Design Professional for this project. The Hauptville Town Engineer worked closely with civil engineers from Thayer Associates to develop three functional requirements for the bridge:

- The new bridge must be constructed on the abutments from the old structure. These existing supports are 24 meters apart.
  [Our 1/40 scale model bridge will actually have a span of 60 centimeters.]

- The bridge must carry two lanes of traffic.
  [Our model bridge must have a roadway width of at least 9 centimeters and at least 9 centimeters of overhead clearance above the deck.]

- The bridge must meet the structural safety requirements of the AASHTO bridge design code.[6]
  [Our model bridge must carry a "traffic load" consisting of a 5 kilogram mass placed on the structure at mid-span.]

The Town Council also added an important **aesthetic requirement.** To preserve the town's historical character, the new Grant Road Bridge should look similar to the old one—a Pratt through truss. The old bridge was made of wrought iron, but the Town Engineer has decided that the new structure will be safer and more practical if it is made of steel.
[For our model, steel will be represented by cardboard from manila file folders.]

The Design

Based on these design requirements, a team of engineers from Thayer Associates has developed **plans and specifications** for the new Grant Road Bridge over Union Creek. The plans and specifications include a structural drawing, isometric drawings of two typical connections, a schedule of truss members, a schedule of connections, and full-scale shop drawings of the structure.

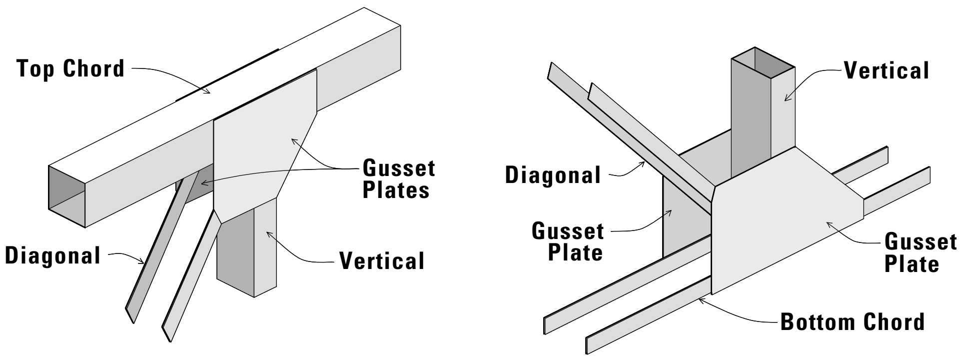
[6] AASHTO is the American Association of State Highway and Transportation Officials, the organization that develops and publishes standard design specifications for bridges in the United States.

Structural Drawing

The structural drawing of the new Grant Road Bridge is designated as Drawing S-1 and is provided on page 1-16. The drawing includes a side elevation, a front elevation, and a plan view. Note that every connection in the structure is designated with a letter—A through N for one main truss and A′ through N′ for the other. These letters are used to identify the members and gusset plates.

Typical Connections

The two isometric drawings below are typical gusset-plate connections found at the top and bottom chords of the main trusses. These drawings illustrate the types of structural members used throughout the Grant Road bridge—hollow tubes for the top chords and verticals; doubled bars for the bottom chords and diagonals. The drawings also show how two gusset plates are used at each connection to hold all of the structural members together. The drawings do not show lateral bracing, struts, or floor beams, which have been omitted for clarity.



Typical top chord and bottom chord connections for the Grant Road Bridge.

Schedule of Truss Members

The Schedule of Truss Members identifies every member required to build the bridge. Note that each member is identified by the two letters corresponding to its endpoints. For example, Member AD is a segment of the bottom chord that goes from Connection A to Connection D.

Component	Members	Type	Approx. Length	# Req'd
Bottom Chords	AD, DG, A′D′, D′G′	4mm bar (double)	30cm	8
Diagonals	CI, DJ, DL, EM C′I′, D′J′, D′L′, E′M′	4mm bar (double)	15cm	16
Verticals	BI, FM, B′I′, F′M′	4mm bar (double)	11cm	8
Top Lateral Bracing	IJ′, I′J, JK′, J′K, KL′, K′ L, LM′, L′M	4mm bar (single)	12cm	8
Portal Bracing	HI′, H′I, MN′, M′N	4mm bar (single)	10cm	4
Top Chords	IK, KM, I′K′, K′M′	10mm x 10mm tube	21cm	4
End Posts	AI, GM, A′I′, G′M′	10mm x 10mm tube	17cm	4
Verticals	CJ, DK, EL, C′J′, D′K′, E′L′	6mm x 10mm tube	12 cm	6
Top Struts	HH′, II′, JJ′, KK′, LL′, MM′, NN′	6mm x 6mm tube	9cm	7
Floor Beams	BB′, CC′, DD′, EE′, FF′	6mm x 15mm tube	10cm	5
Floor Beams	AA′, GG′	28mm x 13mm angle	11cm	2

For this model, a member designated as a 4mm bar is actually a 4mm-wide strip of cardboard. The designation 6mm x 10mm refers to a hollow tube measuring 6mm by 10mm. The lengths shown in the schedule are approximate.

Full-scale Shop Drawings

A full-scale layout drawing of the main trusses (Drawing SD-1) is provided along with this book. This drawing will be used to assemble the main trusses. A full-scale layout drawing of the gusset plates (Drawing SD-2) is also provided on page 1-17. This drawing shows exactly half of the gusset plates required for the bridge.

On an Actual Bridge Project

What are shop drawings?

Shop drawings are detailed drawings of every component that will be part of the completed structure. These drawings are normally prepared by the Constructor and approved by the Design Professional.

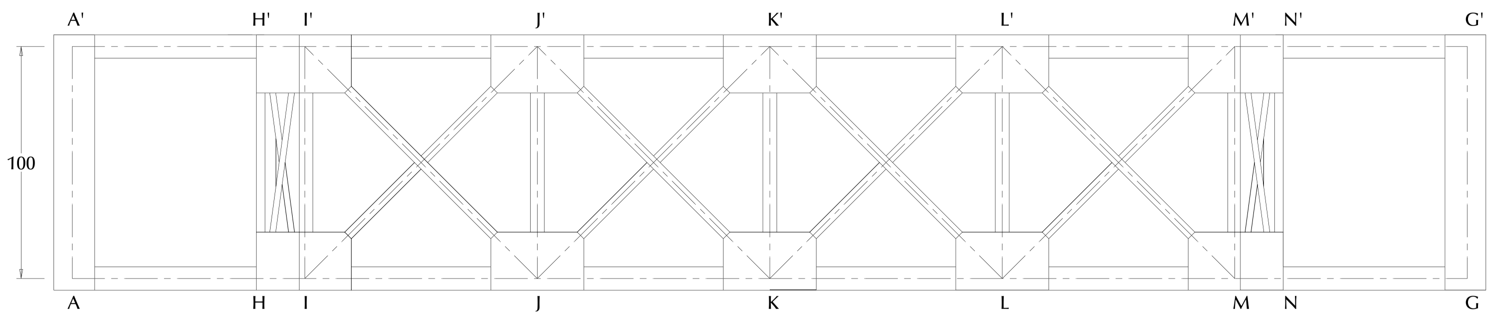
Schedule of Gusset Plates

The Schedule of Gusset Plates designates the gusset plates that will be used for each truss connection in the bridge. The numbers in the "Gusset Plate" column are from Drawing SD-2. The letters in the "Connections" column are from the structural drawing, Drawing S-1.

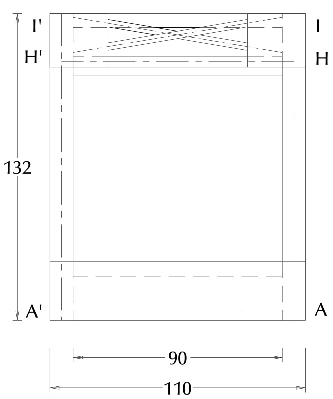
Gusset Plate	Connections	# Req'd
1	A, A′, G, G′	8
2	B, B′, F, F′	8
3	C, C′, E, E′	8
4	D, D′	4
5	I, I′, M, M′	8
6	J, J′, L, L′	8
7	K, K′	4
8	I, I′, M, M′ (top)	4
9	J, J′, K, K′, L, L′ (top)	6

Your Job

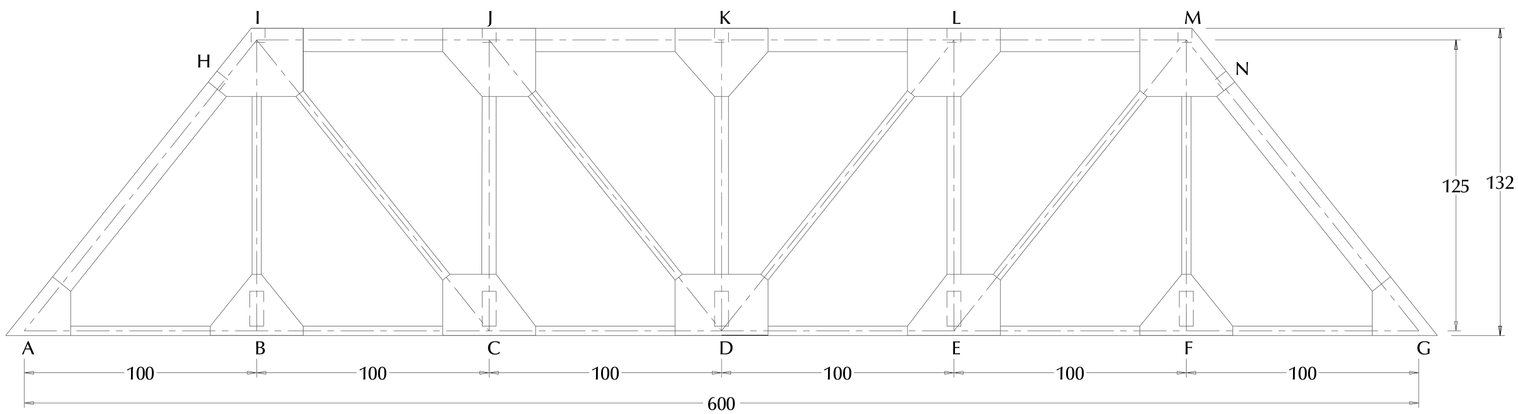
Your construction company has been selected as the Constructor for the Grant Road Bridge project. Your job is to fabricate and construct the Grant Road Bridge, as specified in the Thayer Associates design. As Constructor, you are responsible for completing the project on time, within budget, and to the level of quality specified in the plans and specifications.



Plan View



Front Elevation

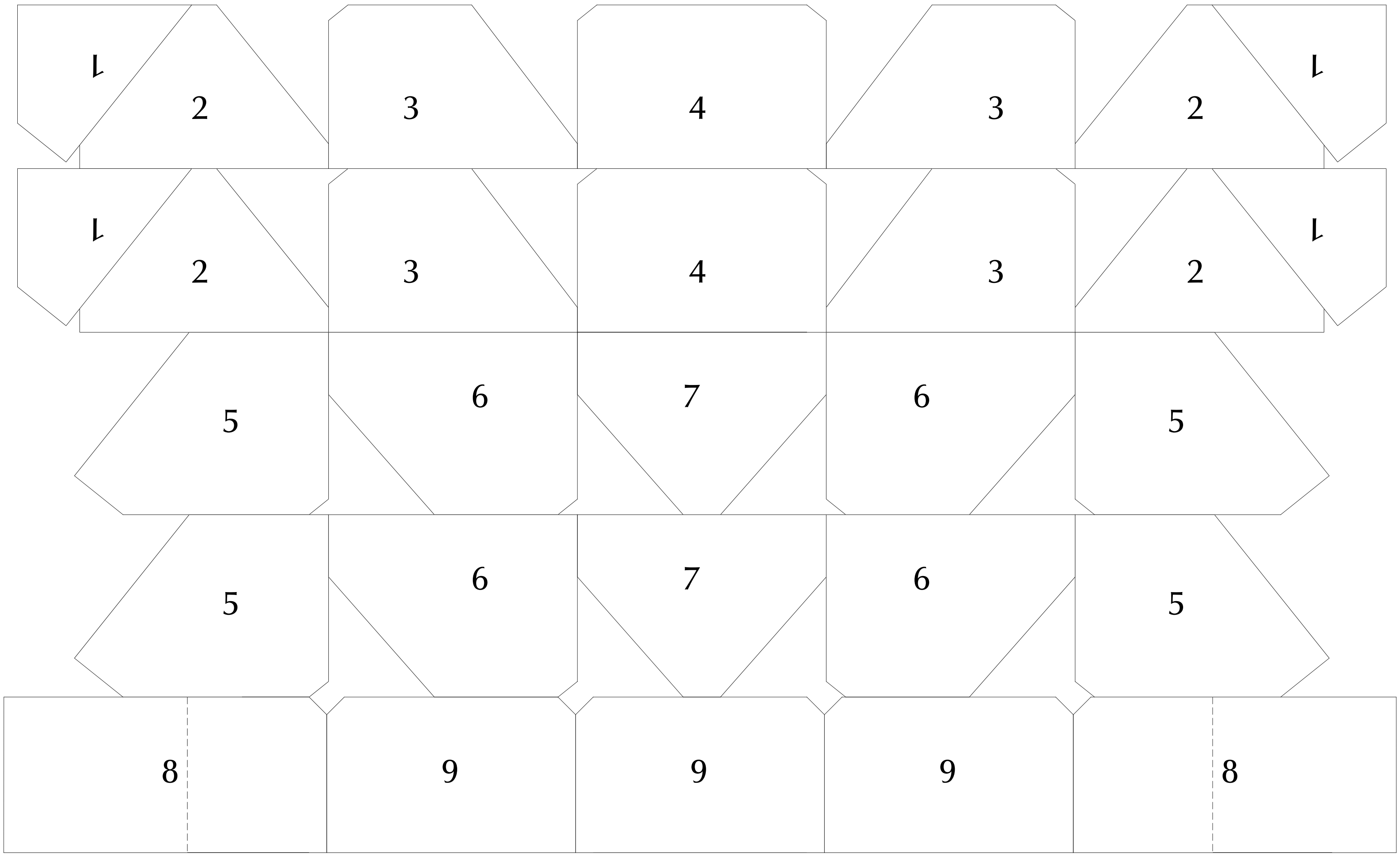


Side Elevation

Notes:

1. All dimensions are in millimeters.
2. All structural members and gusset plates are made from standard file folder material.
3. See Schedule of Truss Members for specific member sizes.

Thayer Associates, Inc. Architects & Engineers	HAUPTVILLE, NEW YORK GRANT ROAD BRIDGE OVER UNION CREEK
Designed by:	
Drawn by:	Reviewed by:
Checked by:	Approved by:
Date:	NOVEMBER 10, 2000
Sheet Reference Number	S-1



Notes:

1. All gusset plates are shown full scale.
2. This layout shows exactly half the number of gusset plates required for the bridge.
3. See the Schedule of Gusset Plates for the location of each plate.

Thayer Associates, Inc.
Architects & Engineers

Designed by:

Drawn by:

Checked by:

GRANT ROAD BRIDGE

GUSSET PLATE LAYOUT

Reviewed by:

Approved by:

Date: NOVEMBER 10, 2000

Sheet Reference Number SD-2

The Plan

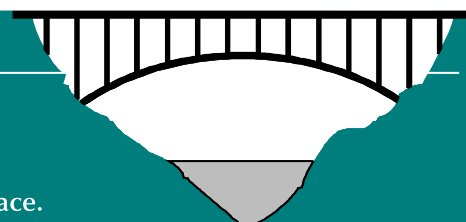
Congratulations on your selection as the Constructor for the Grant Road Bridge project! You have received the plans and specifications, and the Owner has given you the **notice to proceed**—an official authorization to start work on the project.

At the start of any construction project, the Constructor's first priority is to develop a detailed plan for building the facility. For this project, our construction management plan is relatively simple. It consists of the following six major steps, which should be performed in sequence:

- Obtain the necessary supplies and tools.
- Prefabricate the structural members and connections.
- Set up the construction site.
- Build the structure.
- Perform a quality control inspection.
- Put the bridge into service.

Put on your hard hat and your steel-tipped boots. It's time to get to work!

On an Actual Bridge Project



Safety comes first.

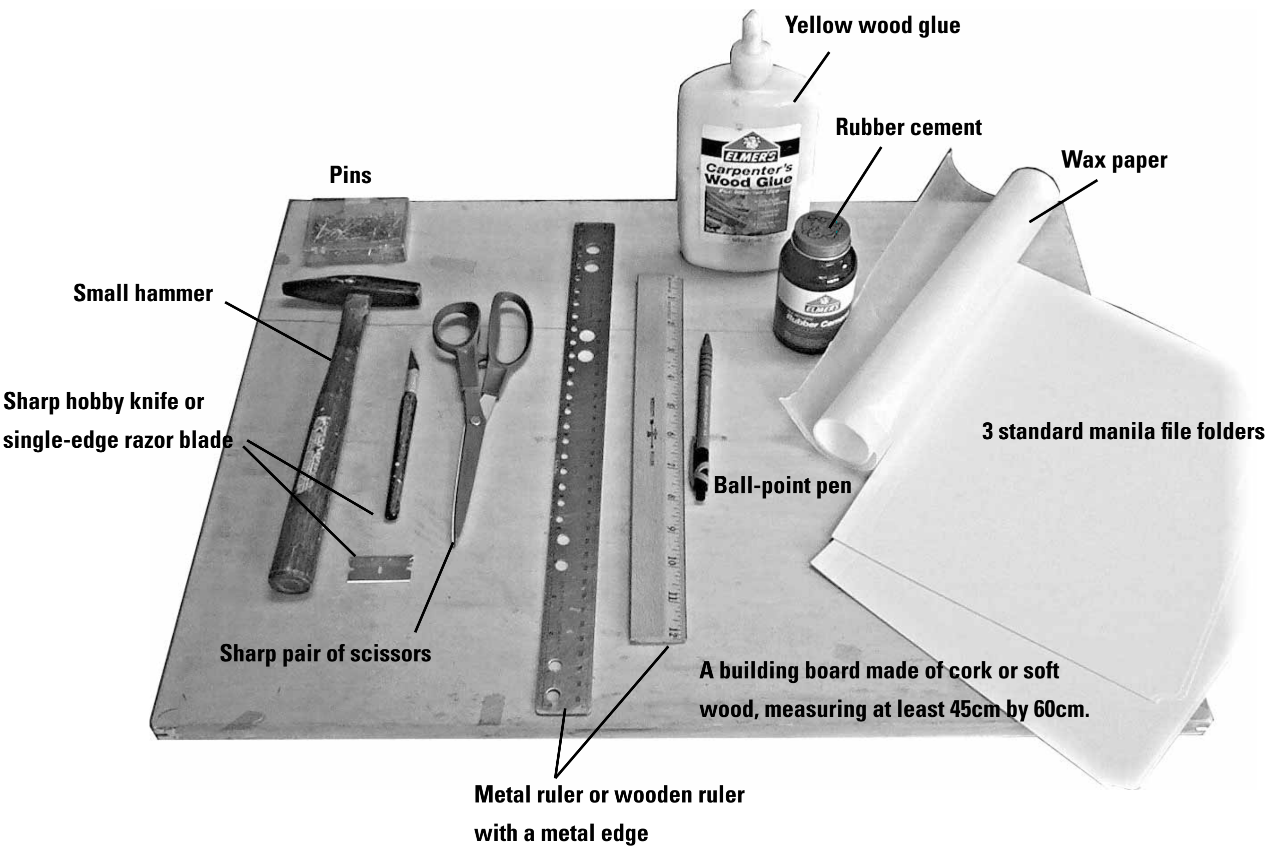
A construction site can be a very dangerous place.

Everyone on the site is responsible for ensuring that the work gets done without serious injury or loss of life. The Design Professional must ensure that the structure can be built safely. The Constructor must ensure that every worker has the necessary safety equipment and that everyone on the site follows appropriate safety procedures. The Project Manager oversees the safety of the entire project. Getting a project done can never be as important as the life of one worker.

Obtain the Necessary Supplies and Tools

To build the Grant Road Bridge, you will need the supplies and tools shown below. In addition, you'll need the full-size bridge plans that were included with this book.

- 3 standard manila file folders
- A building board made of cork or soft wood, measuring at least 45cm by 60cm.
- Wax paper
- Pins
- Small hammer
- Sharp pair of scissors
- Sharp hobby knife or single-edge razor blade
- Metal ruler or wooden ruler with a metal edge
- Ball-point pen
- Yellow wood glue
- Rubber cement

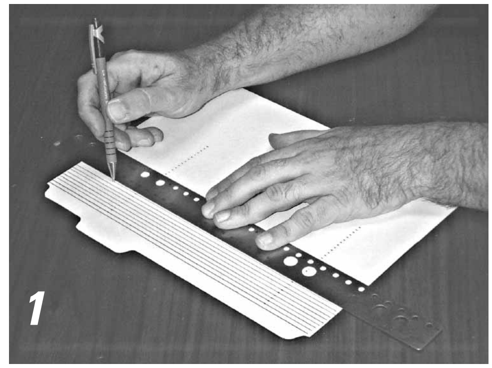


Some of the layout work will be easier if you use a draftsman's T-square and a drawing board. You'll also need a metric scale to weigh the books that we will be using to load-test the completed structure.

Prefabricate the Structural Members and Connections

Prefabricate the Bars

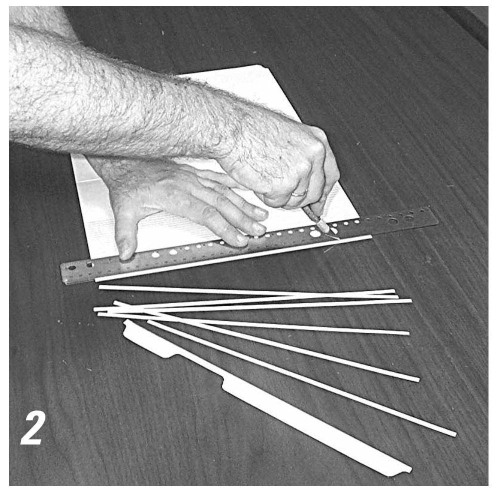
The bottom chords, diagonals, and hip verticals specified in the Schedule of Truss Members are all 4mm-wide bars—actually strips of cardboard sliced from a manila file folder. If you are using a standard 30cm-wide file folder, you'll need to slice 30 strips to make all of these members. Here's how to do it:



1) Using a ruler and a pen, carefully measure and draw 31 parallel lines exactly 4mm apart. Draw the lines parallel to the longer dimension of the folder, so that each line is 30cm long. (You can draw these lines more easily and more precisely if you use a T-square and a drawing board. Step 4 shows how the T-square is used.)

2) Place the marked file folder on your building board, and use a sharp knife and a metal ruler to cut along each line. Don't press too hard, or you'll have trouble making a straight cut. It will probably take two or three passes with the knife to cut all the way through the cardboard. (You could also use a scissors for this job, but you would find it much more difficult to make straight cuts.)

Don't cut the strips to length at this time. You'll do this when you build the trusses.



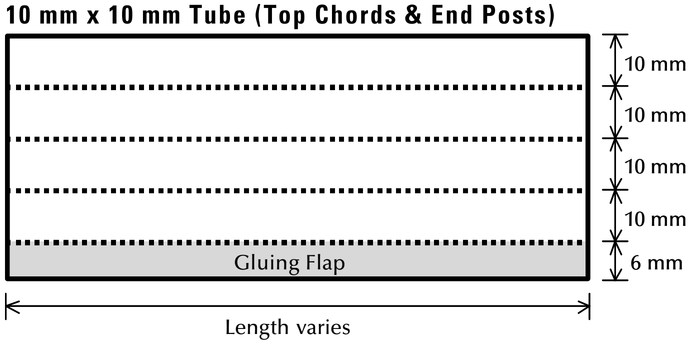
Prefabricate the Tubes

Tubes are a bit harder to make, because each one must be cut out, then folded four times and cemented together. It may take a few minutes to make each of these members, but do the job carefully—the load-carrying capacity of your bridge depends on it!

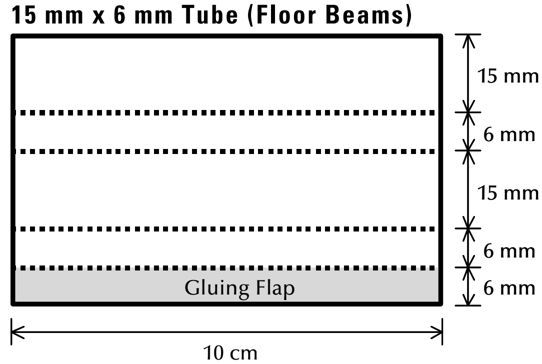
Here's how to build the tubes:

3) These diagrams show how each of the four different types of tubes should be laid out. The solid lines indicate the outline of the member—you will cut along these lines. The dotted lines indicate where the member will be folded.

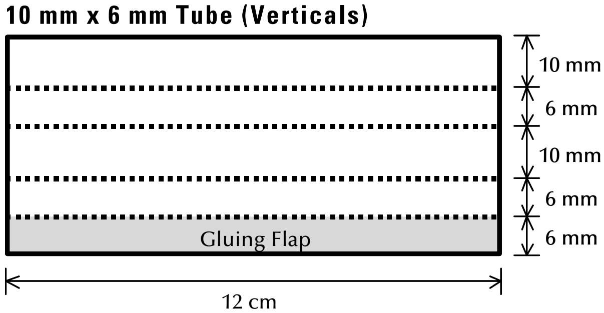
10 mm x 10 mm Tube (Top Chords & End Posts)



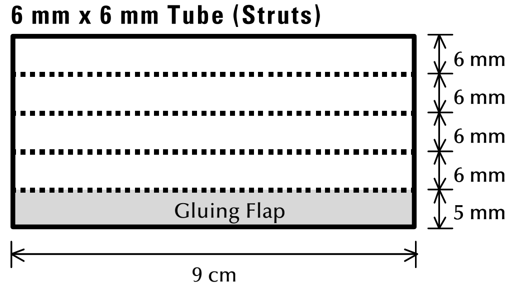
15 mm x 6 mm Tube (Floor Beams)



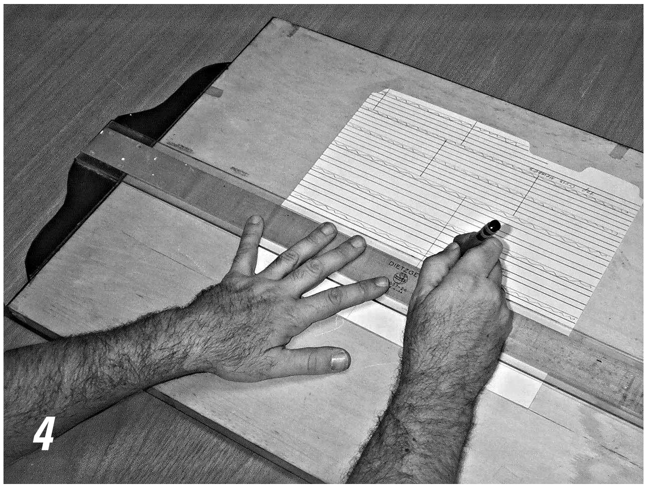
10 mm x 6 mm Tube (Verticals)



6 mm x 6 mm Tube (Struts)

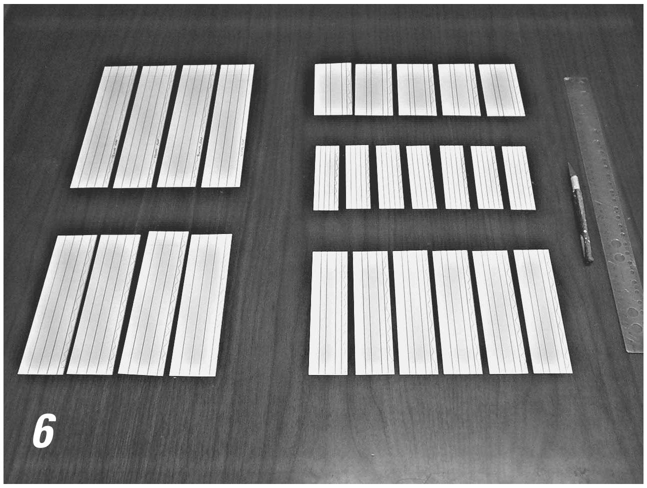


4) Using a ball-point pen and a ruler (or a T-square, as shown in the photo), lay out all the tubes specified in the Schedule of Truss Members. Start by measuring and marking the parallel edges and fold-lines as accurately as possible on the file-folder cardboard. When you draw the fold-lines, *press hard* with the pen. The indentations made by the pen will make the cardboard easier to fold. Now draw perpendicular lines to indicate the lengths of the members, as specified in the Schedule of Truss Members. It is best to mark the lengths a bit oversize now, then trim them to the exact length later, when you build the trusses. In planning your layout, note that you can get two verticals, three struts, or three floor beams from each 30cm length of material.

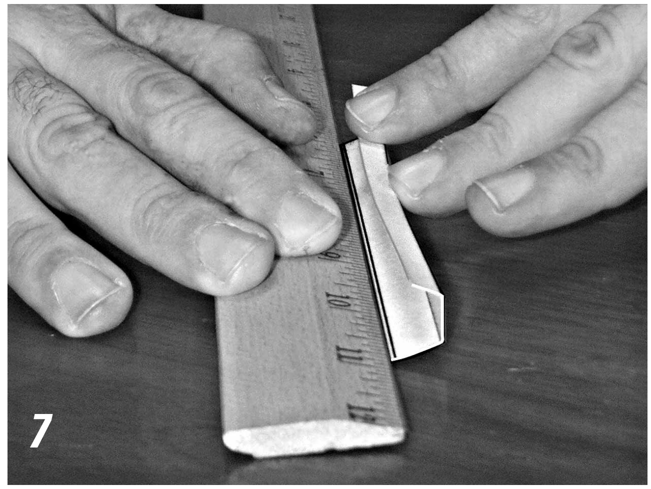


5) Once you have drawn all the tubes, cut them out with a scissors or knife. Remember *not* to cut the fold lines.

6) When all of the members have been cut out, you are ready to begin folding them into tubes.

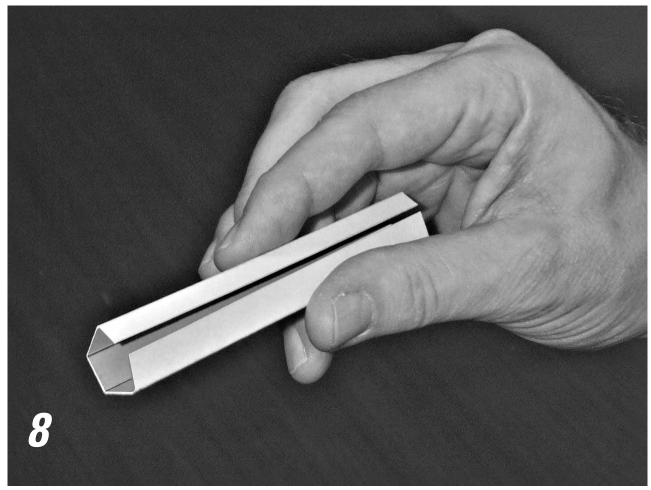


7) Starting with one of the 10mm x 10mm members, fold and crease each of the four fold-lines. To help you make the folds straight, lay a ruler along each fold-line as you bend the cardboard.



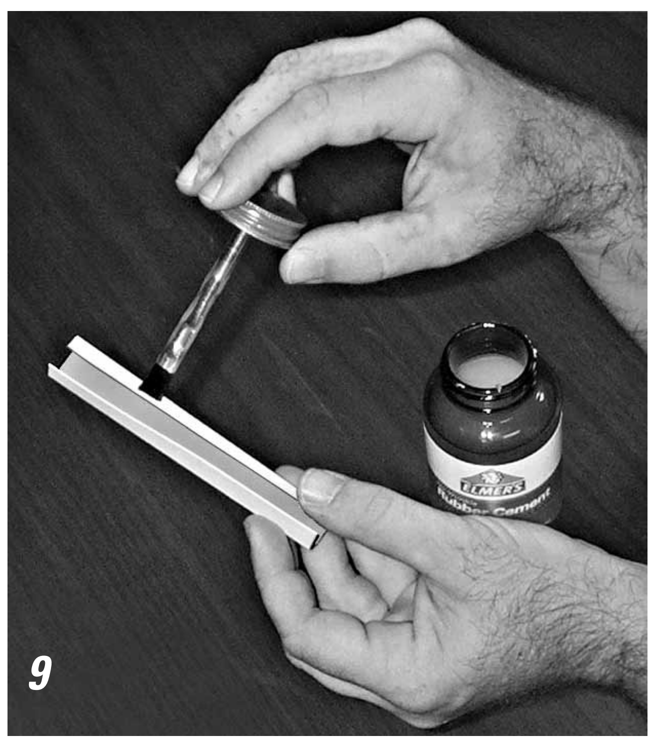
7

8) Once you have made all four folds, the member will form a square tube, as shown here.



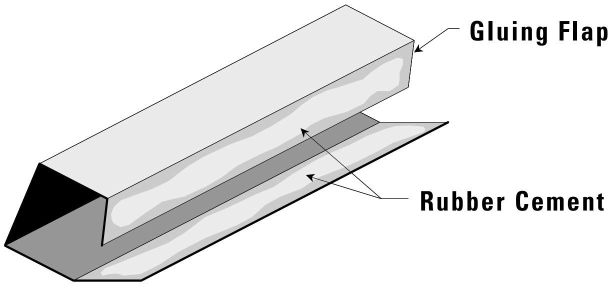
8

9) We will use rubber cement to attach the "gluing flap" to the other free edge of the tube. Rubber cement works well for his job, because it dries very quickly and because these joints do not require the greater strength provided by wood glue.



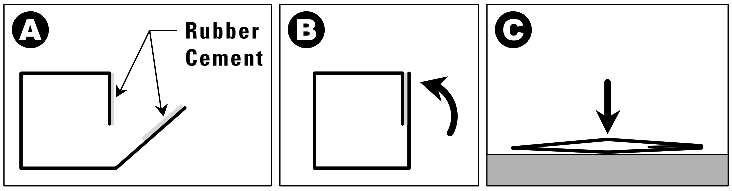
9

10) Apply an even coat of rubber cement to both surfaces that will be bonded together, as shown here. Wait 2-3 minutes, until the cement is tacky. (If the cement is still wet when you put the glued surfaces together, you'll have to hold them together as the cement dries. If the cement is sticky, but not quite dry, the two surfaces will bond together as soon as they touch. To get the timing right, you might want to practice on a scrap piece of cardboard before actually gluing the tubes together.)



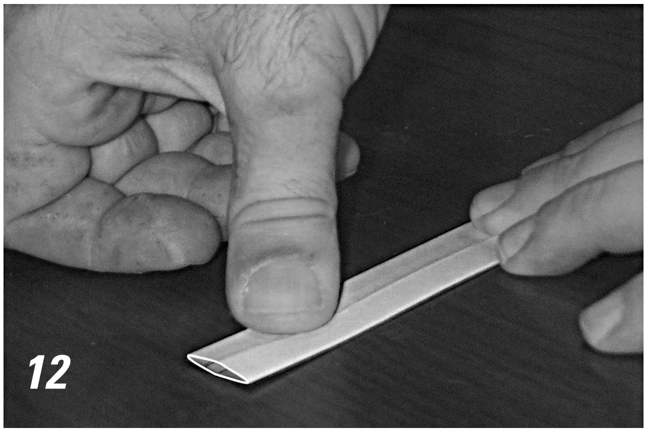
10

11) Now carefully bring the two cemented surfaces together **(A)** to form a square cross-section **(B)**. Note that the gluing flap goes on the *inside* of the completed tube. Immediately flatten the tube on you building board **(C)** and hold it flat for a few seconds, until the cement sets.

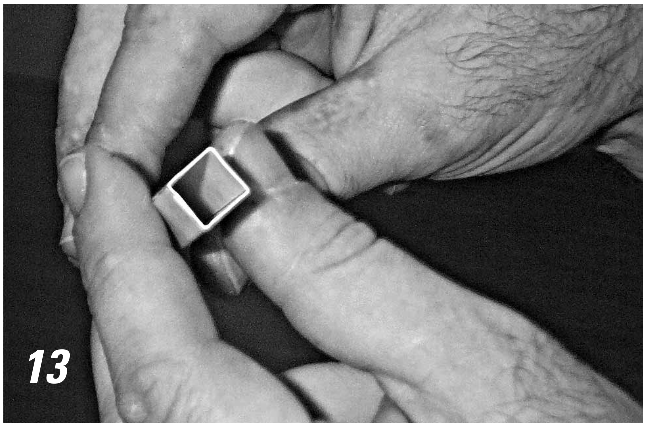


11

12) Flattening the tube in this manner does two things. First, it ensures that the cemented surfaces are firmly in contact with each other; and second, it ensures that the completed member is not curved or twisted.



13) After the rubber cement has dried, pick up the tube and reshape it back into a square cross-section.



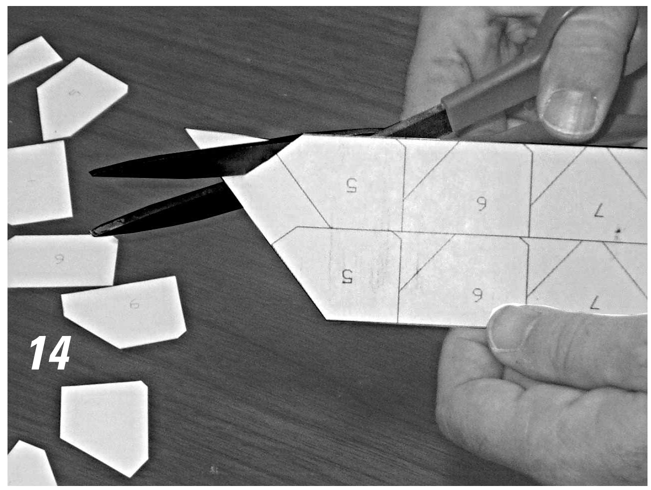
Now repeat Steps 7 through 13 for all of the remaining tube members.

Prefabricate the Gusset Plates

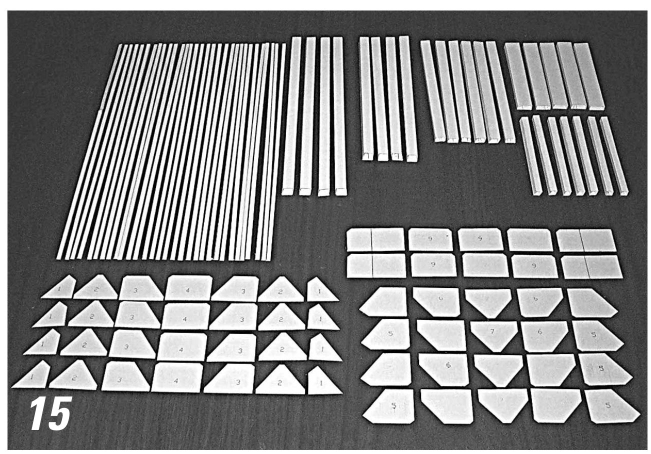
Our example bridge uses a total of 58 gusset plates to connect the structural members together. If you wanted to make these components in the easiest possible way, you could simply cut out 58 cardboard rectangles, each measuring 40mm x 30mm. These would work fine; however, they would not look authentic, and they would use a lot more cardboard than necessary. The gusset plates shown in Drawing SD-2 more accurately depict real truss connections.

To make the authentic gusset plates, the full-scale layout provided on Drawing SD-2 must be transferred to a file folder. There are three possible ways to accomplish this: (1) you can lay a sheet of carbon paper on the file folder, then lay Drawing SD-2 on top of the carbon paper, and trace over the outline of each gusset plate with a pen or pencil; (2) you can cut out the gusset plates from Drawing SD-2, lay them on the file folder, and trace around each one with a sharp pencil or pen; or (3) if you have access to a copy machine with a "single sheet feeder," you can photocopy the patterns directly onto file-folder card board. You'll need to cut the folders to 8 ½" x 11" size, so they will run through the single sheet feeder without jamming. Clearly this third option is easiest and most accurate. No matter which method you use, remember that you will need to do the process twice, because Drawing SD-2 only shows half of the required gusset plates.

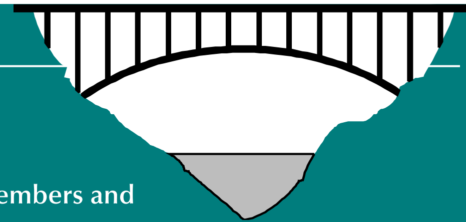
14) Once you have transferred the gusset plate patterns onto the cardboard, carefully cut out each gusset plate with a sharp scissors.



15) The prefabrication of structural members is now complete. We're ready to start building!

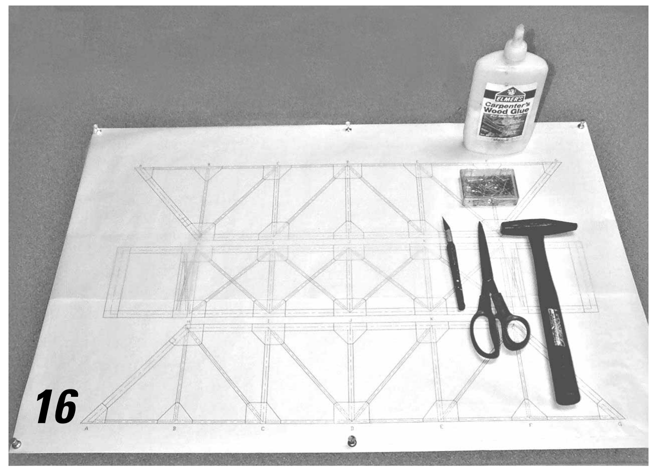


On an Actual Bridge Project



Who prefabricates structural components?

On an actual bridge project, steel structural members and connections are made by a **steel fabricator**. The steel fabricator is a member of the Construction Team and is usually a subcontractor. The fabricator's work is done in a shop, not on the construction site, in order to achieve the highest possible quality.



Set up the Construction Site

16) Find a large, flat tabletop to use as your construction site. Place your building board on the tabletop. Place Drawing SD-1 on top of the board, and put a layer of wax paper over it. Use a few pins or staples to keep everything in place.

On an Actual Bridge Project

How does the Constructor set up the construction site?

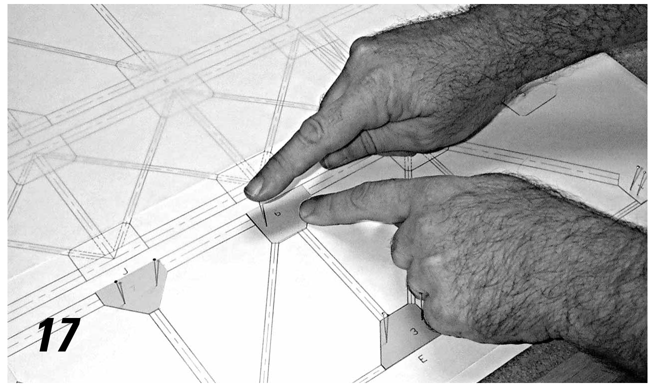
The setup of a construction site varies from project to project. However, on just about any major project site, the Constructor will provide the following:

- A construction office with telephones, computers, storage fo important documents, and workspace for the Superintendent—the on-site construction supervisor.
- Space for on-site storage of construction materials.
- Access to the site for construction vehicles.
- A location for the crane that will be used to lift pieces of the structure into place.
- Traffic control and safety fencing to keep unauthorized vehicles and pedestrians away from the site.
- Electrical power for tools and equipment.

Build the Structure

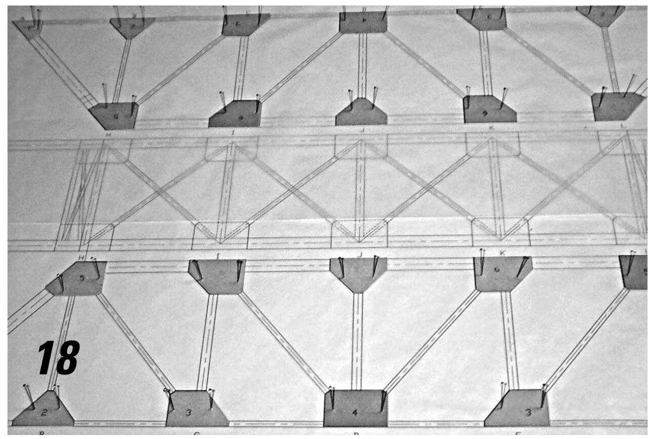
Build the Main Trusses

17) Start by placing the appropriate gusset plates directly onto the drawings of the two main trusses, at the locations designated in the Schedule of Gusset Plates. Hold each gusset plate in place with two pins. (If you use only one pin, the plate will be able to rotate out of position.) Put each pin through a point on the gusset plate where no members will be attached; otherwise, the pins will be in the way when you glue the members to the gusset plates.



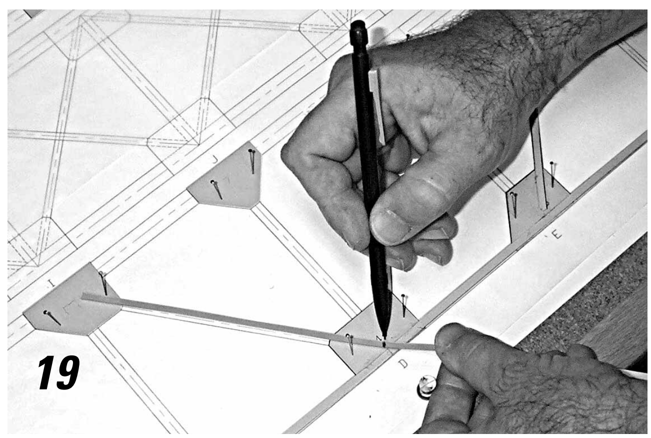
17

18) When you're done, you will have 24 gusset plates pinned to the board.



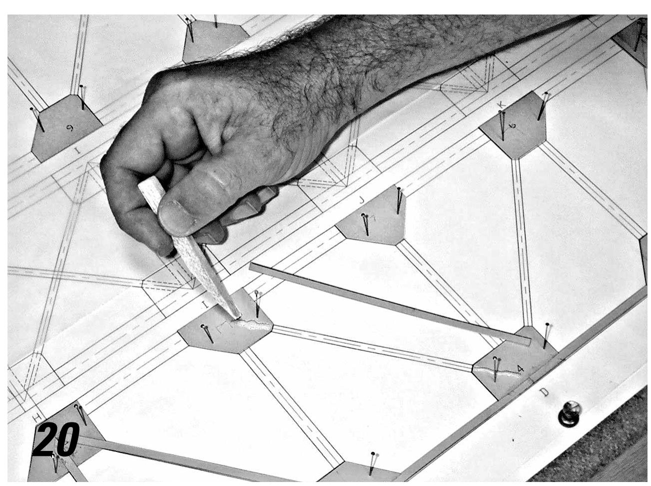
18

19) Now add the 4mm bars. Select one of the cardboard strips you prefabricated in Step 2. Place it in the correct position, and mark its length with a pencil or pen. (The photo shows Member DJ, a diagonal, being marked. Note that the bottom chord members are already in place.)



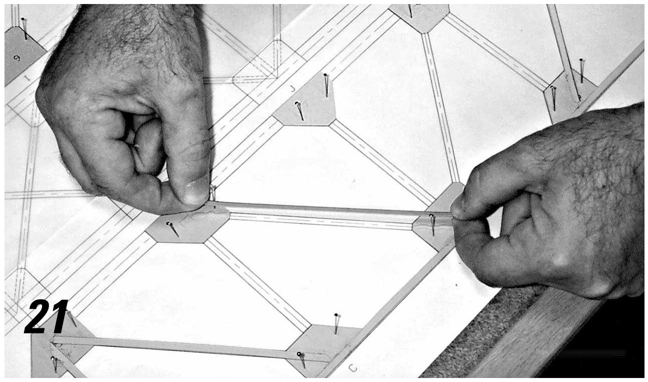
19

20) Spread wood glue on the two gusset plates to which the member will be attached. You can apply the glue directly from the bottle; however, you will find that you can do a neater job if you use a scrap piece of cardboard or wood as an applicator, as shown here. Do not use rubber cement for these joints! It's not strong enough.

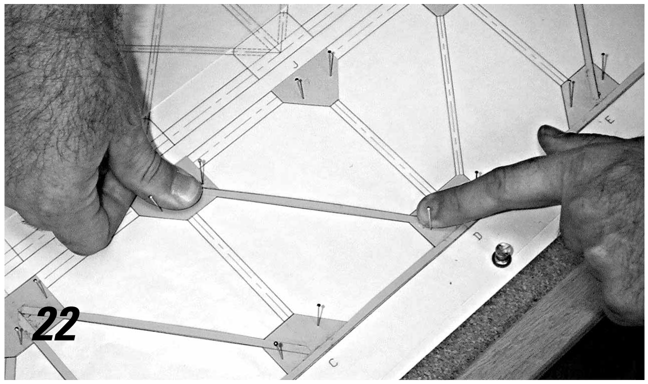


20

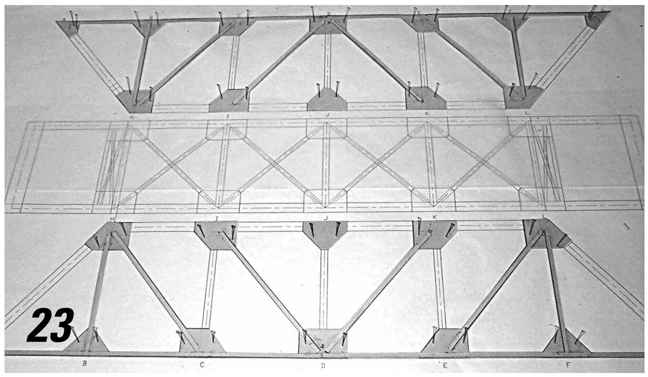
21) Now place the 4mm strip onto the gusset plates, using the drawing beneath to ensure that it is in the correct position.



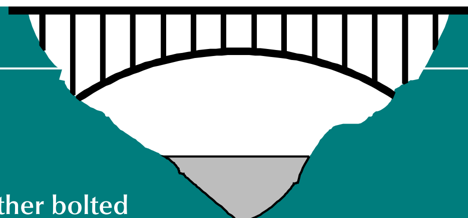
22) Press firmly on both ends of the member, and hold it in place for about 30 seconds, until the glue starts to set. Be careful not to glue your fingers to the gusset plates!



23) Repeat Steps 19 through 22 for each of the 16 bars on the two trusses. Note that the two outermost verticals on each truss are bars. The remaining three verticals are tubes, which will be attached in the next series of steps.



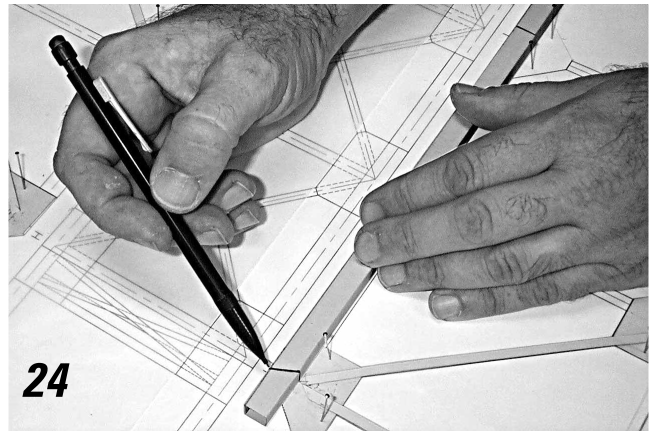
On an Actual Bridge Project



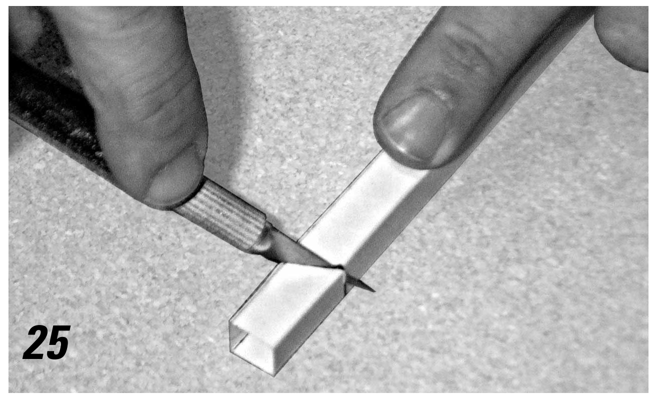
How are members attached to gusset plates?

On modern bridges, structural members are either bolted or welded to the gusset plates. When two pieces of steel are welded, they are actually fused together to make a single piece of steel. Welds are strong and relatively inexpensive, but they require highly skilled workers and specialized equipment to make. Thus welded connections are often used for portions of a structure that can be assembled in the shop by the steel fabricator. Bolted connections do not require specialized equipment and are relatively easy to assemble; thus, they are often used for field connections—those that are assembled on the construction site, rather than in the fabrication shop.

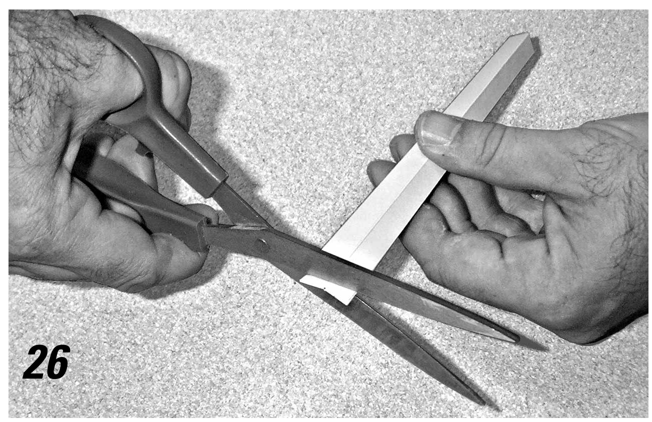
24) Now you will attach the tubes to the gusset plates, but only on one of the two trusses—the one closer to you. Start by placing one of the 10mm x 10mm tubes into position on the top chord and marking its length with a pencil or pen. (Member IK is shown in the photo.)



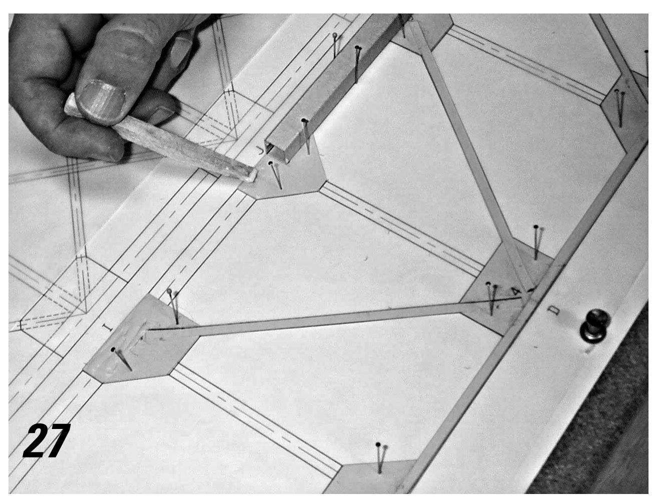
25) Cut this member to the correct length. Some of the tubes—like this one—must be cut at an angle. You'll need to use your knife or razor blade to make these cuts.



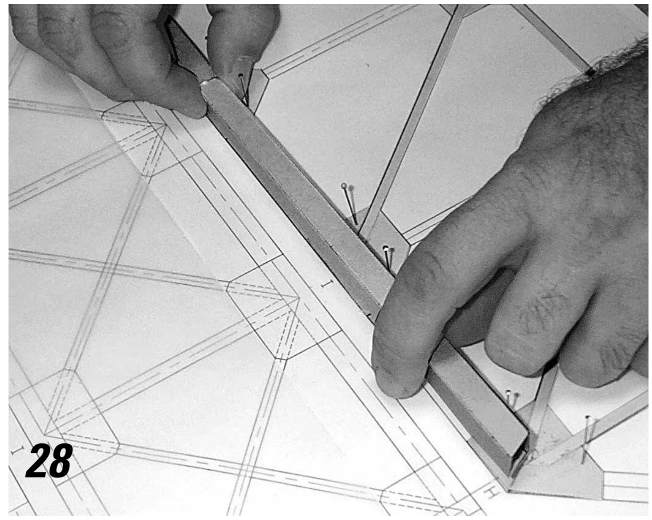
26) Other members must be cut square. For these cuts, it is easier to flatten the end of the tube, and use a scissors.



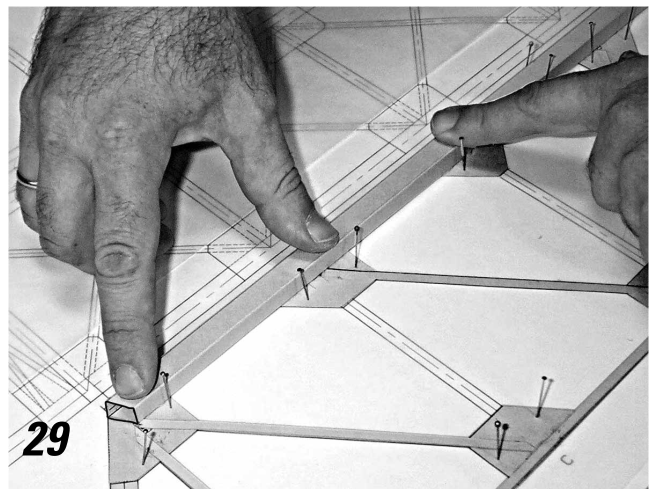
27) Now apply glue to the two gusset plates.



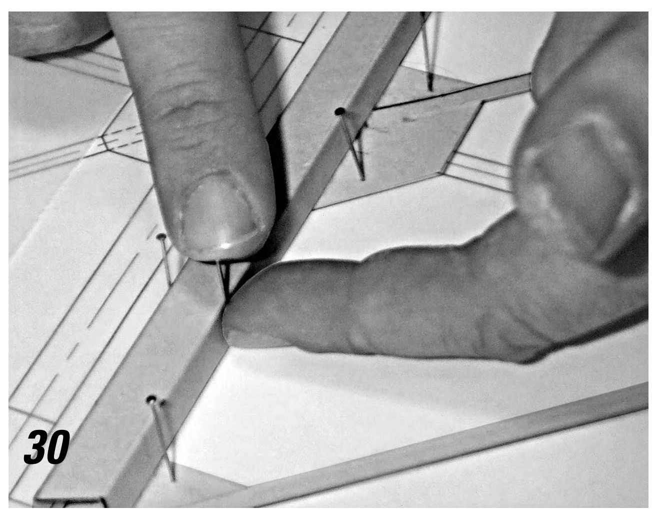
28) Put the member into position.



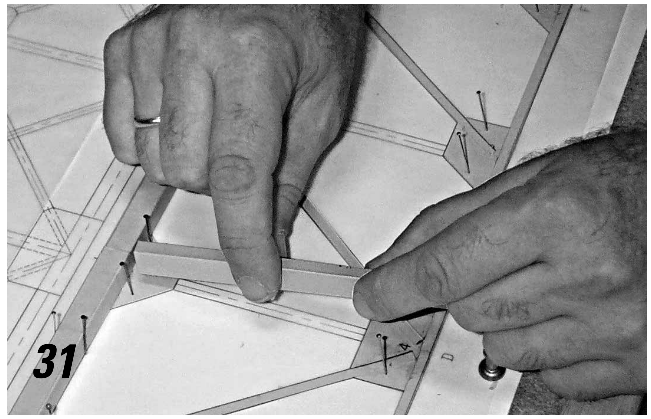
29) And hold the member in place until the glue sets.



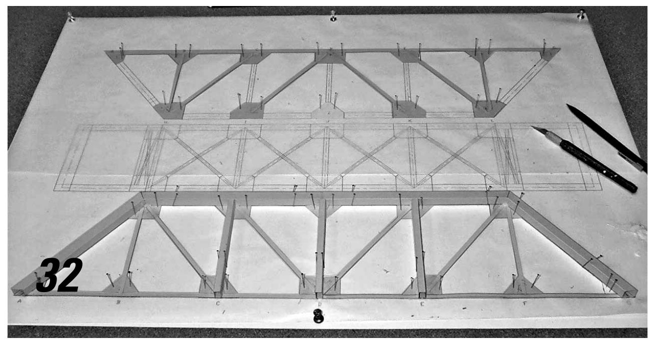
30) As you assemble the main trusses, it is very important to keep the cross-section of each tube as close to square as possible. Do this by pushing a pin into the building board on either side of each tube, as shown. The pins will keep the sides of the tube vertical as you assemble the remainder of the truss.



31) Repeat Steps 24 through 30 for the remaining tubes. Be sure to use the correct sizes—10mm x 10mm tubes for the top chords and end posts, and 10mm x 6mm tubes for the three interior verticals. The photo shows the vertical member DK being glued into position. Note that the verticals should be placed with their shorter (6mm) side flat on the building board and the longer (10mm) side standing upright.

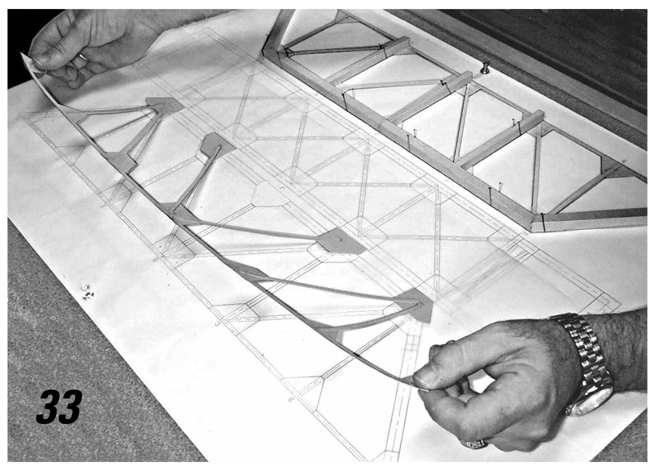


32) When all of the tubes are glued in place, the result should look like this. Note again that the tubes are only glued to one of the two trusses on the building board.

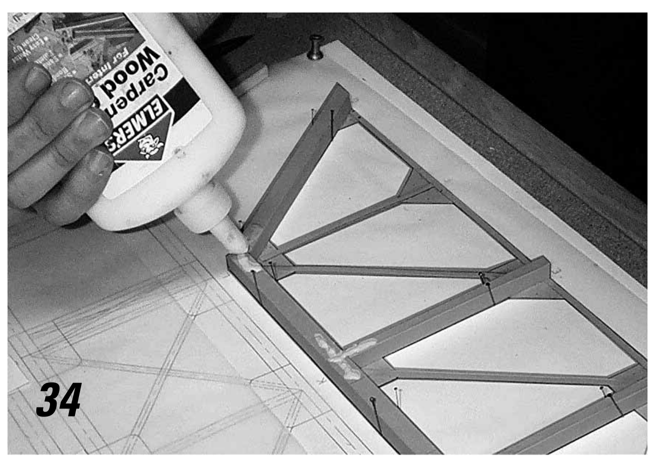


33) The two subassemblies currently on the board are actually two halves of the *same* truss. Now we will put them together. Begin with the "upper half"—the one composed only of gusset plates and bars. Remove all of the pins holding the upper half to the building board, and lift it free. *Carefully* separate this subassembly from the wax paper. If you tear one of these members, your bridge will probably not be able to carry its specified 5 kilogram load. Once you have separated the subassembly from the wax paper, put it aside.

On the "lower half"—the one closest to you—pull out all of the pins in the gusset plates, but do not remove the pins you added in Step 30.



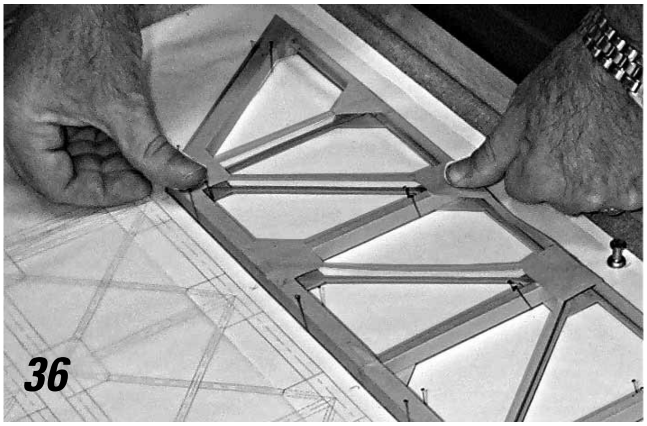
34) Put glue at the appropriate locations on the lower half of the truss—the places where the upper gusset plates will connect to the tubes on the lower half.



35) Carefully place the upper half directly on top of the lower half. Ensure that the two halves are aligned before the glue starts to set.

35

36) Note that, when you assemble the two halves, you are creating the *doubled bars* specified in the Schedule of Truss Members. It is very important that both of the bars in each pair are stretched tightly between gusset plates. If one is tight and the other is loose, the two will not share load equally and may fail prematurely. Use your thumbs to pull the upper bars tight, as shown.



36

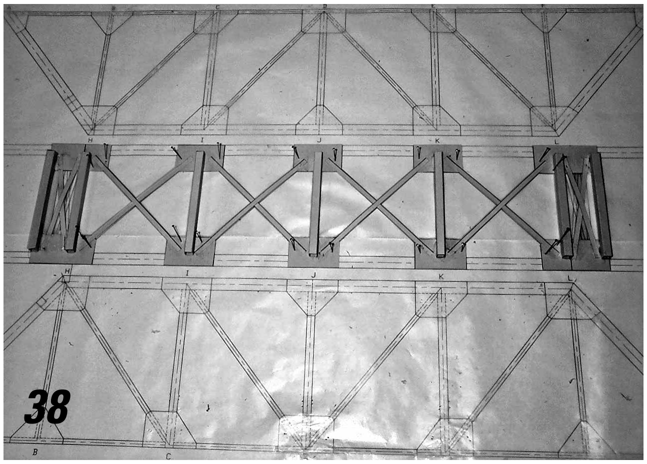
37) At this point, the assembled truss is missing only the upper gusset plate at Connection K. This one was left behind on the building board, because it is not attached to any bars on the upper half of the truss. Glue this final gusset plate in place.

Now remove the truss from the board, and set it aside. Using exactly the same procedure (Steps 17 through 37) build a second *identical* main truss.

37

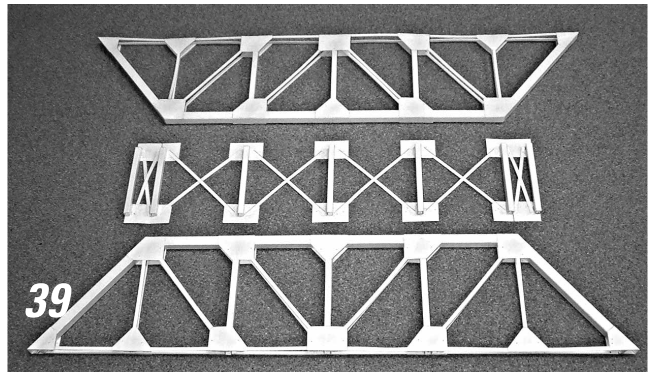
Build the Lateral Bracing Subassembly

38) Following the same procedure you used for the main trusses, assemble the lateral bracing subassembly, which will connect the two main trusses together. Start by pinning the gusset plates to the board; then add the lateral bracing, made of *single* 4mm bars. Finally add the struts, which are made of 6mm x 6mm tubes, all exactly 9 cm long.



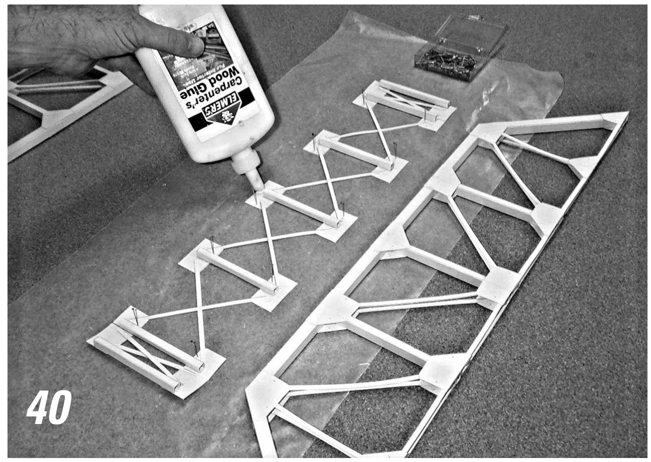
38

39) When the lateral bracing subassembly is complete, remove it from the building board. The three major subassemblies are now done. We are ready to assemble the three-dimensional structure.

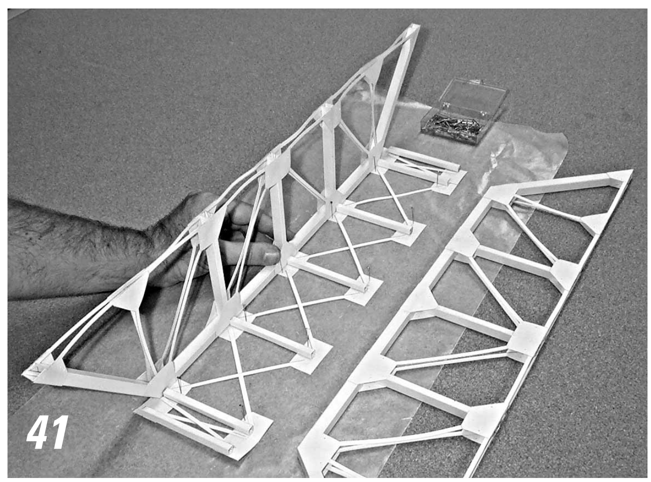


Connect the Two Trusses Together

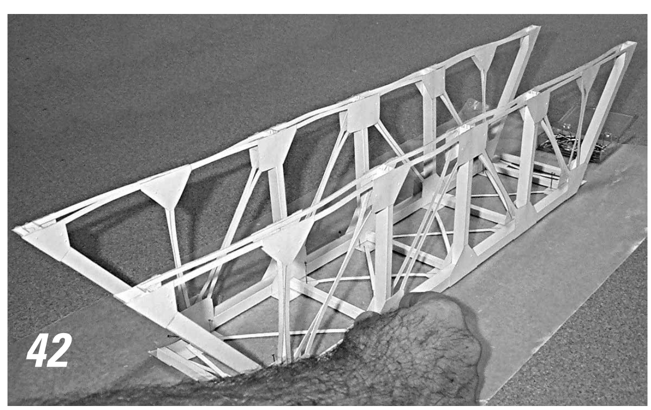
40) Place the lateral bracing subassembly flat on the building board. Apply glue to all five gusset plates on one side.



41) Position one of the two main trusses. (Note that you are assembling the bridge upside down.) Once the truss is in position, check to ensure that it is vertical, and hold it in place for a minute or so.



42) Now add the second truss in the same manner.



43) You may find it helpful to use pins on the outsides of the two trusses to hold the subassemblies together while the glue sets. Do not remove any pins or move the bridge until the glue has dried completely.

43

Q3

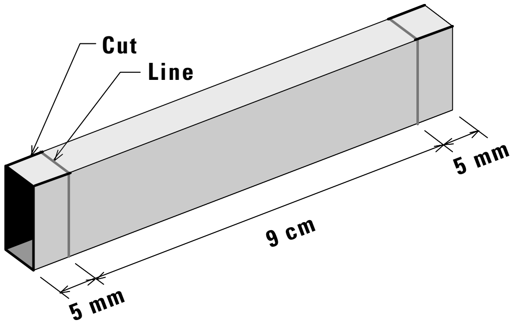
What are the purposes of the struts and lateral bracing?

As you can see from Steps 40 – 42, the struts and lateral bracing help connect the two main trusses together. What other purposes do you think these members serve?

Add Floor Beams

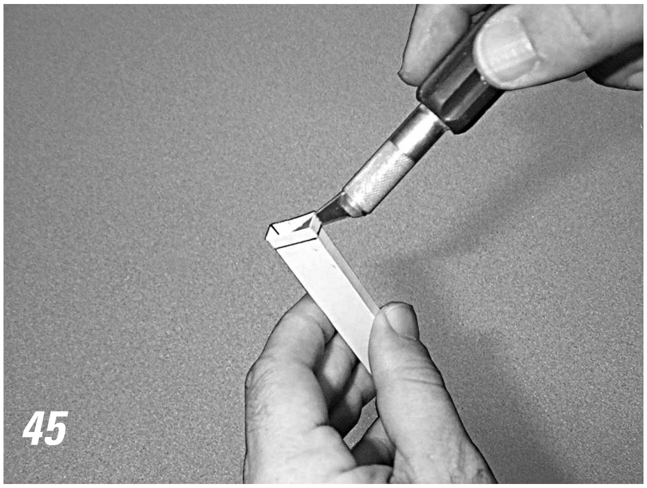
Just as the struts connect the two trusses together at their top chords, the floor beams connect the trusses together at their bottom chords. As you might have noticed when you prefabricated these members, the floor beams are one centimeter longer than the struts. Why? Since there are no gusset plates to connect the floor beams to the bottom chord, we will use the outer 5mm on each end of the floor beams to form *connecting angles*. These angles will connect the floor beams to the gusset plates on the inside of each truss.

44) Draw two lines completely around the tube, as shown on this diagram. (An easy way to do this is to flatten the tube, then use a ruler to draw the lines.) The two lines should be *exactly* 9cm apart.



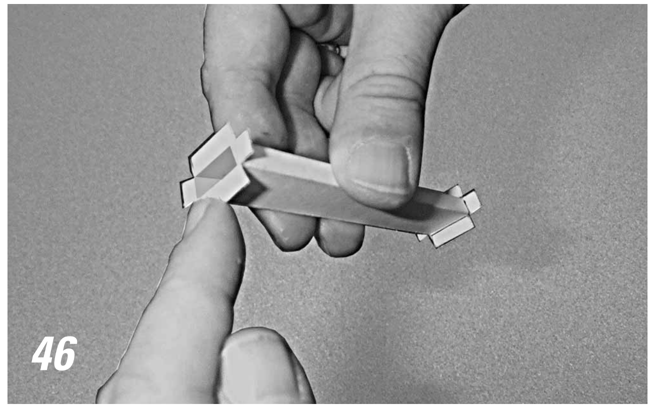
44

45) Now use your knife to slice through all four corners of the beam, as shown in the photo. Cut *only* as far as the line you drew in Step 44.

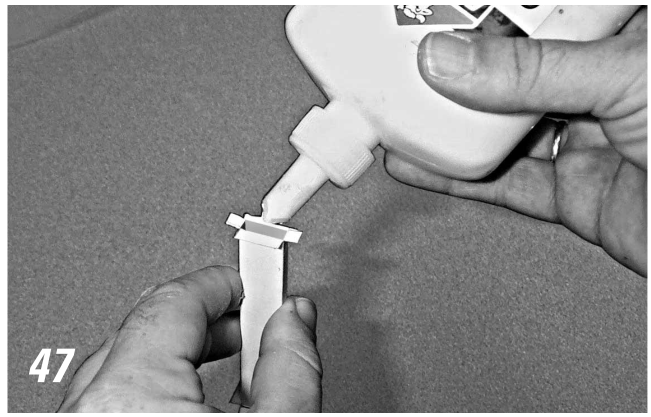


45

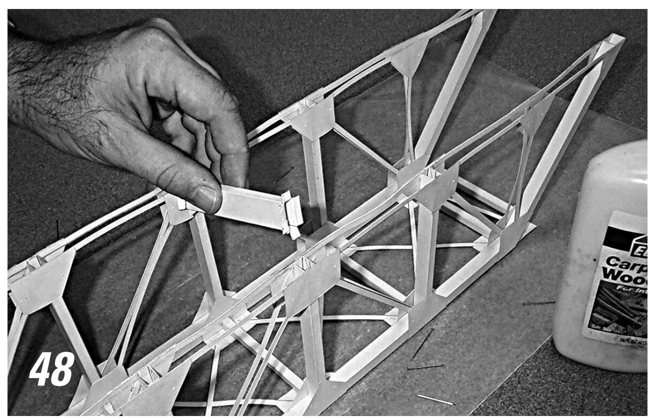
46) At each end of the beam, fold all four sides outward along the line. These four flaps form the connecting angles that we will use to attach the beam to the bottom chord.


46

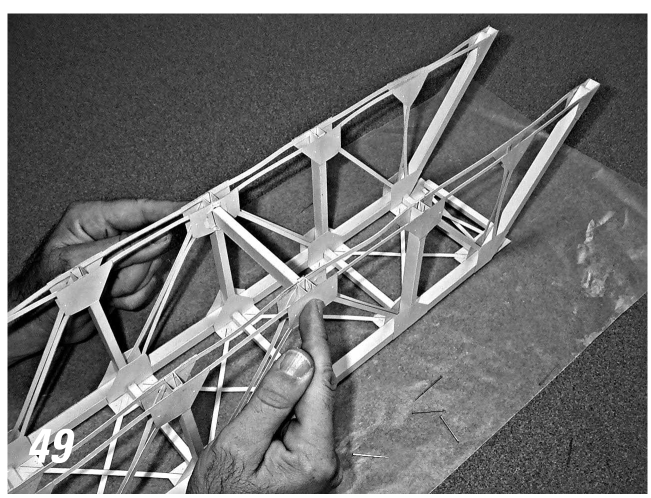
47) Apply glue to all four flaps.


47

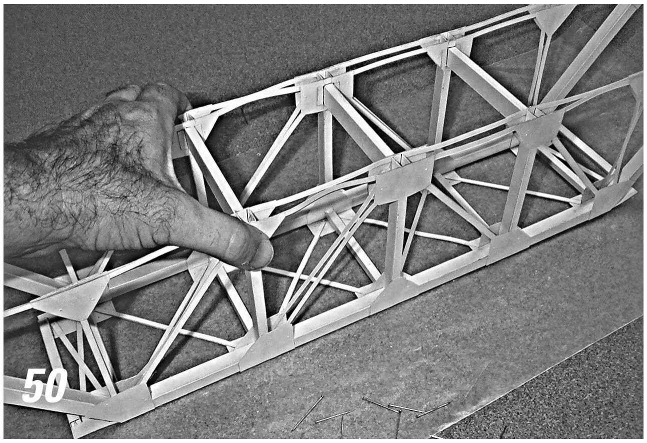
48) Place the beam between Connections D and D′, at the center of the bottom chords. Note the orientation of the beam—the larger dimension is vertical.


48

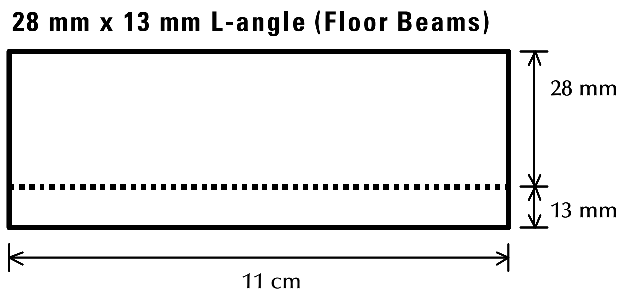
49) Press inward on the two gusset plates until the glue sets.


49

50) Now repeat the process for floor beams CC′ and EE′.

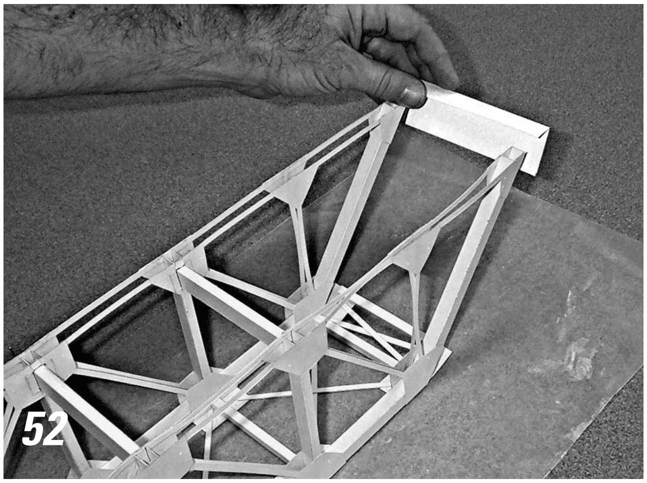


51) Cut out two rectangles of file-folder cardboard with these dimensions, and fold each one sharply along the dotted line. These are the two end floor beams AA′ and GG′.

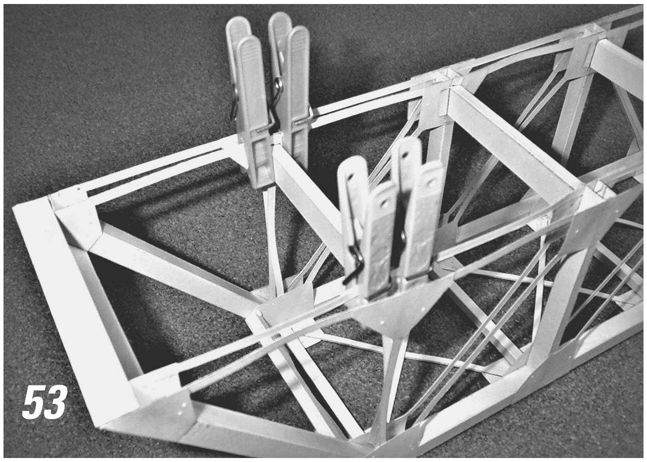


51

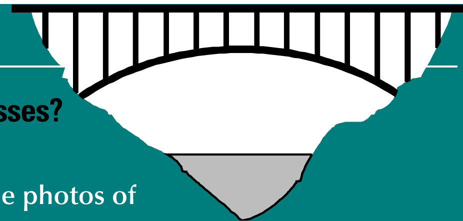
52) Glue the end floor beams in place, as shown here.



53) Glue the two remaining floor beams (BB′ and FF′) in place. Because there is no tube between the pairs of gusset plates at Connections B, B′, F, and F′, you may find it helpful to clamp the beam in place with four clothespins, as shown.



On an Actual Bridge Project



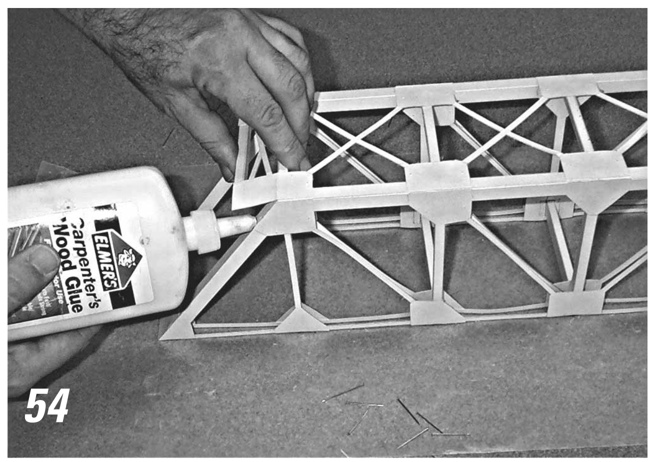
How are the floor beams attached to the main trusses?

In the Gallery of Truss Bridges (Appendix A), the photos of Bridges 9 and 12 show a typical arrangement used to attach the floor beams to the main trusses in older pin-connected bridges. In both of these bridges, the floor beam is suspended from the pin by two U-shaped bolts. Modern trusses generally use connecting angels very similar to the ones we used in our model.

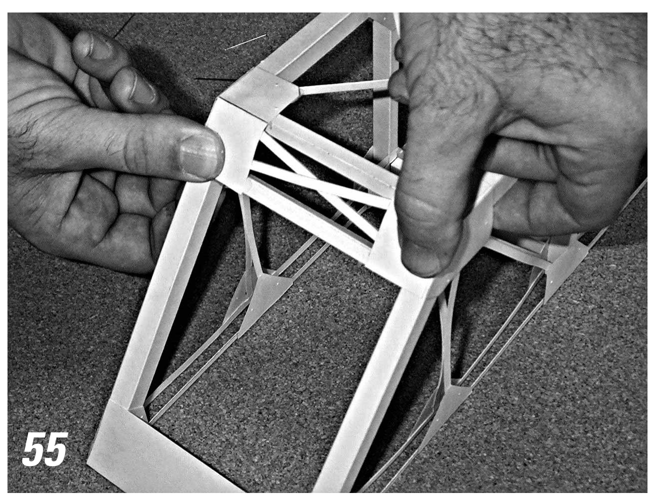
Add the Portal Bracing

You have already created the portal bracing. You did it when you made the lateral bracing subassembly in Step 38. Now all you need to do is glue it into place.

54) Apply glue to the top front of the two end posts.



55) Fold the portal bracing down onto the end posts and hold in place until the glue sets. Do the same for the portal bracing on the opposite end of the bridge.



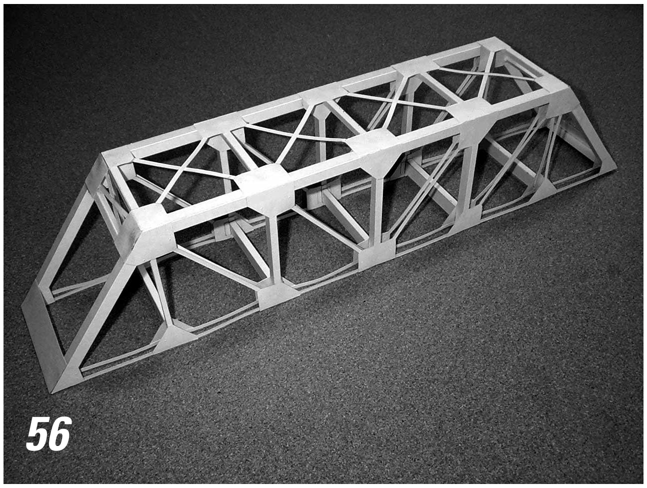
Q4

What is the purpose of the portal bracing?

The portal bracing serves an important purpose in a through truss bridge. What do you think that purpose is? To answer this question, look at your own model bridge, and try to visualize how it might fail if the portal bracing were not present.

Perform a Quality Control Inspection

56) The bridge is finished! But before you place it into service, you should carefully inspect the structure to ensure that it has been built according to the plans and specifications. Are all the structural members positioned correctly? Are any of them cut, torn, or dented? If so, repair or reinforce these points before you load the structure. Are all of the members firmly attached to their gusset plates? If not, add more glue to these joints. It is important that the connections are stronger than the members themselves.



Q5

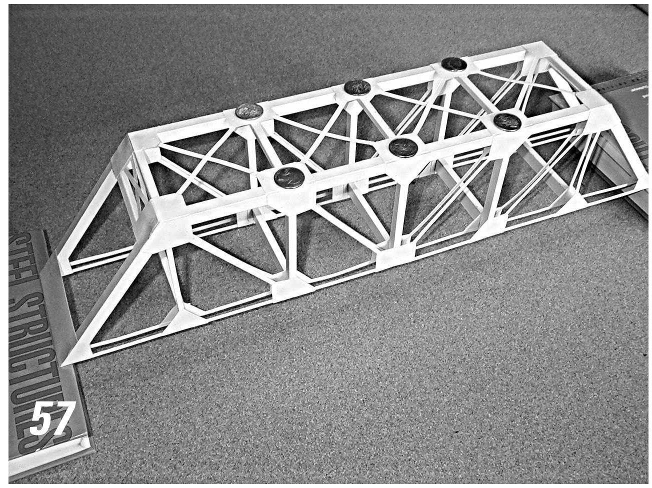
Why are truss bridges less common today?

Trusses are used much less commonly in bridge structures today than they were a hundred years ago. Based on your own experience with the Grant Road Bridge project, why do you think truss bridges are less common today?

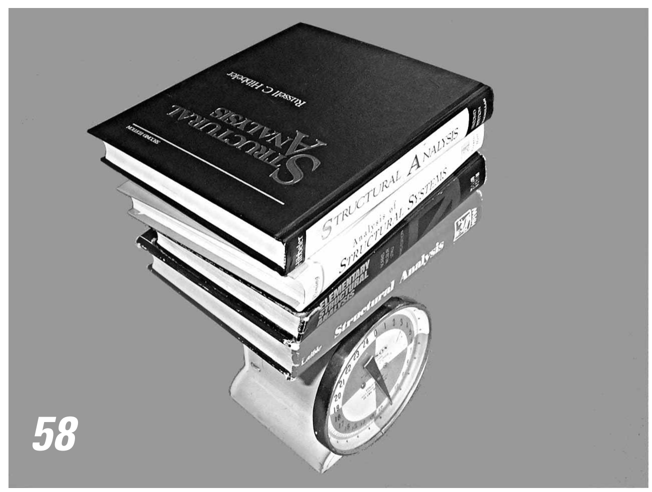
Place the Bridge Into Service

If this were a real bridge, we would be ready to hold a ribbon-cutting ceremony and open the bridge to traffic. For our model bridge, we'll simulate the grand opening by applying the prescribed 5-kilogram load to the structure. We will use a stack of books as the load.

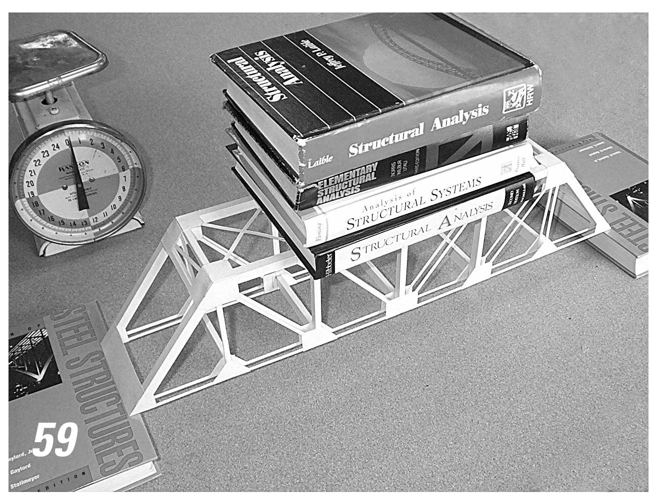
57) To prepare for the load test, set up two books as abutments approximately 59 cm apart, and put the bridge on top of them. Place a coin on top of each gusset plate at Connections J, J', K, K', L, and L'. Trusses are designed to be loaded *only* at the joints; the coins will ensure that the weight of the books is transmitted to the main trusses only at these locations.



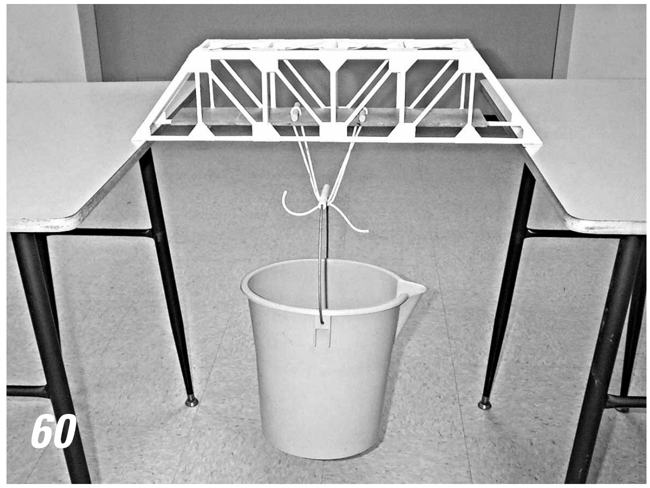
58) Using a metric scale, experiment with various books until you have assembled a stack with a mass of approximately 5 kilograms.



59) Now place the books gently, one at a time onto the top of the truss. Keep them centered. Leave the full 5-kilogram stack of books is in place for a few minutes.

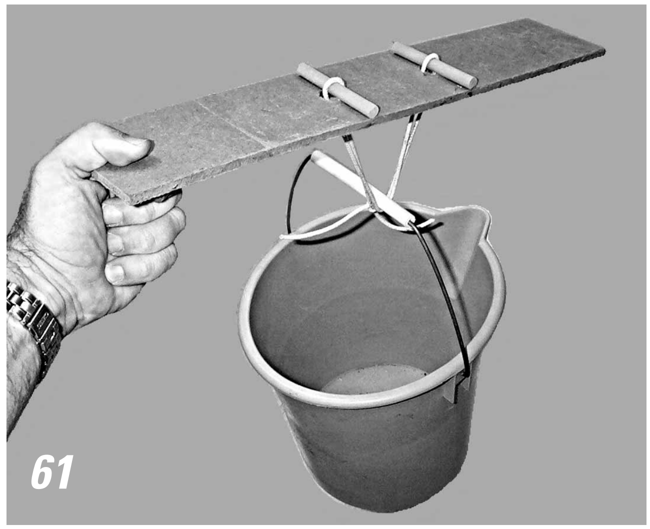


60) Another way to load-test the bridge is to suspend a bucket filled with sand from the floor beams. The total mass of the bucket, sand, and loading platform should be 5 kilograms.



60

61) You'll need to build a wooden platform like this one to support the bucket. The platform is 8 cm wide and 50 cm long. It has two 1.5 cm holes drilled 10 cm apart in the center. The bucket hangs from a single loop of heavy cord. The two ends of the loop are pushed through the holes in the platform and held in place with two pencils or wooden dowels. The platform rests on all five interior floor beams of the bridge. Don't just hang the bucket from floor beam DD'; the concentrated weight will probably rip the floor beam out of the structure.



61

Q6

Which method of loading is better?

Compare the two methods of loading described in Steps 59 and 60. What are the advantages of each method?

If your bridge carries the prescribed 5-kilogram loading, congratulations! Your bridge construction project is a success! Weigh the bridge. You'll find that it has a mass of about 55 grams—a strength-to-weight ratio of over 90. That's not bad for a structure made of paper.

If you built your bridge well, it should actually be able to carry about 10 kilograms before it collapses. But resist the temptation to load it to failure! Engineers take great pride in the physical products of their work, and you should too. You've put a lot of time and effort into this project. Save your bridge; don't destroy it. And remember that engineers *always* design structures to stand up, not to collapse!

Q7

Why is the bridge "too strong?"

The functional requirements for the Grant Road Bridge specify that the structure must be capable of carrying a 5 kilogram mass. The actual capacity of the structure is about 10 kilograms. Why did the structural engineer design the bridge with so much extra capacity?

While your bridge still has the load in place, take a moment to examine how the structure is carrying the load. You can learn a lot about structural engineering just by carefully observing how the members in this bridge behave when a load is applied. Note that some members are stretched tightly in tension. Some are slack—they appear to have no internal force at all. Others are in compression, though these are a bit harder to identify.

Q8

How does your model bridge carry load?

Which members of the Grant Road Bridge are in tension? Which are in compression?

Q9

Why tubes and bars?

Why did the structural engineer specify tubes for some members and bars for others?

Q10

How does construction quality affect structural performance?

Based on your own experience on this project, explain how the quality of the Constructor's work affects the performance of a structure. If you make errors in construction, or if your glue joints are not strong enough, or if parts of the structure are damaged during assembly, how are the function and appearance of the structure affected?

Conclusion

The bridge construction project is complete. In doing the project, you had the opportunity to learn a lot about bridges, about construction, and about some basic principles of structural engineering. You also practiced some techniques for working with a rather unusual construction material. Perhaps you had some fun too. But you haven't actually *done* any engineering yet. Stay tuned for Learning Activity #2, where we will design and conduct a series of experiments to determine the strengths of structural members—the first step in the process of designing your own bridge.